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CONDUCTED JOINTLY BY THE

STATE DEPARTMENT OF AGRICULTURE

AND THE

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RALEIGH AND WEST RALEIGH

SELF-STERILITY IN DEWBERRIES
AND BLACKBERRIES

THE NORTH CAROLINA AGRICULTURAL EXPERIMENT STATION

CONDUCTED JOINTLY BY THE
STATE DEPARTMENT OF AGRICULTURE

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N. C. COLLEGE OF AGRICULTURE AND MECHANIC ARTS

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SELF-STERILITY IN DEWBERRIES AND BLACKBERRIES

BY L. R. DETJEN.

INTRODUCTION

The phenomenon of sterility may be caused by any one of a number of various factors. It may be caused by external agencies, such as excessive heat, cold, moisture, and a host of other such conditions; but, more frequently, it can be traced to a deep-seated internal origin.

Sterility is encountered almost everywhere; it ramifies all branches of the plant and animal kingdoms. As an agent in the hands of organic evolution, sterility plays a rôle of prime importance, while to the breeder of improved forms it not infrequently becomes a menace and a stumbling block to further progress.

Sterility is a factor which is confined not only to the spheres of organic improvement and to evolution in general, but also to that of the production of fruit crops. In the latter field it becomes a factor of the utmost importance. In the planning of the older fruit plantations the factors of sterility were not recognized, and hence the innumerable financial failures, which, by a little knowledge of the comparative fertility of varieties, might well have been averted. Examples of this faulty planning of fruit plantations are very numerous, and only a few concrete examples will suffice to evince the real significance of the factors of sterility. Bartlett pear trees when set in large solid blocks have generally proven unprofitable to the grower. V. R. Gardner in his "Pollination of the Sweet Cherry," Oregon Experiment Station Bulletin, No. 116, points out the fact that among the more recent plantings of the sweet cherries, the fruit growers in Oregon have unconsciously selected varieties such as Napoleon, Bing, Lambert, and others, which are not only self-sterile, but also intersterile, as recent investigations have proven. In such cases even the selection of a list of varieties may not always constitute a remedy, and such practice when not carefully done may be no better than the planting of a whole block of a single self-sterile variety.

The large vineyards of *Rotundifolia* grapes in North Carolina give evidence of a lack of a sufficient number of pollinizers. These vineyards were planted upon the supposition that the different varieties of Muscadine grapes were self-fertile; but even so, in many instances provision was made for the cross-pollination of the different varieties. Later investigations regarding the self-sterility of *rotundifolia* grapes (N. C. Bulletin, No. 209) produced evidence that all of the cultivated varieties of these grapes are self-sterile, and also inter-sterile, and that

for successful fruit production the presence of male vines in large vineyards is absolutely essential.

Even the growers of small fruits are not immune from the harmful effects of sterility when certain varieties are planted in solid blocks. Fortunately for the commercial growers in the eastern States, the leading varieties of dewberries and blackberries are self-fertile and produce abundantly even when planted in large solid areas. However, there are many excellent varieties on the markets which are more or less influenced by the factor of sterility, and which, with judicious care in the selection of varieties with regard to pollination, can be made to yield profitable crops. In fact, there are a number of varieties which are likely to prove to be just as good as the chief commercial varieties of the present day, barring this one defect.

Object of the Experiment.—The prime object of the experiment under discussion was to investigate the question of sterility among varieties of dewberries and blackberries. This question resolves itself into the following three lines of investigation: first, to ascertain which varieties of dewberries and which varieties of blackberries are self-fertile and which are self-sterile; second, to discover, if possible, the cause or causes of this sterility; and, third, if possible, to suggest remedies.

STERILITY AMONG DEWBERRIES AND BLACKBERRIES.

Varieties Tested.—In order to provide sufficient material in the way of varieties to carry on this sterility test, the following varieties were secured and planted under ordinary field conditions:

<i>Dewberries</i>	<i>Hybrids</i>	<i>Blackberries</i>
Austin	Cox	Blowers
Chestnut	Ruth	Dallas
Grandee	Haupt	Early Cluster
Limekiln	Rathbun	Early Harvest
Lucretia	McDonald	Eldorado
Manatee	Wilson	Illinois
Munroe	Sorsby	Kenoyer
Rogers	Spalding	King
Elijah, No. 2		Mersereau
Premo		Minnewaski
San Jacinto		Snyder
White		

Method of Procedure.—The method used to test these varieties for self-sterility may be stated as follows: whole flower-clusters, and often-times several of them, were inclosed in bags so as to exclude all foreign pollen. Some of these bags were ordinary half-pound paper sacks, while others were made of cloth. The latter were made of Pacific lawn, which is a light, gauzy, but very fine-meshed fabric, and which successfully keeps out all foreign pollen.

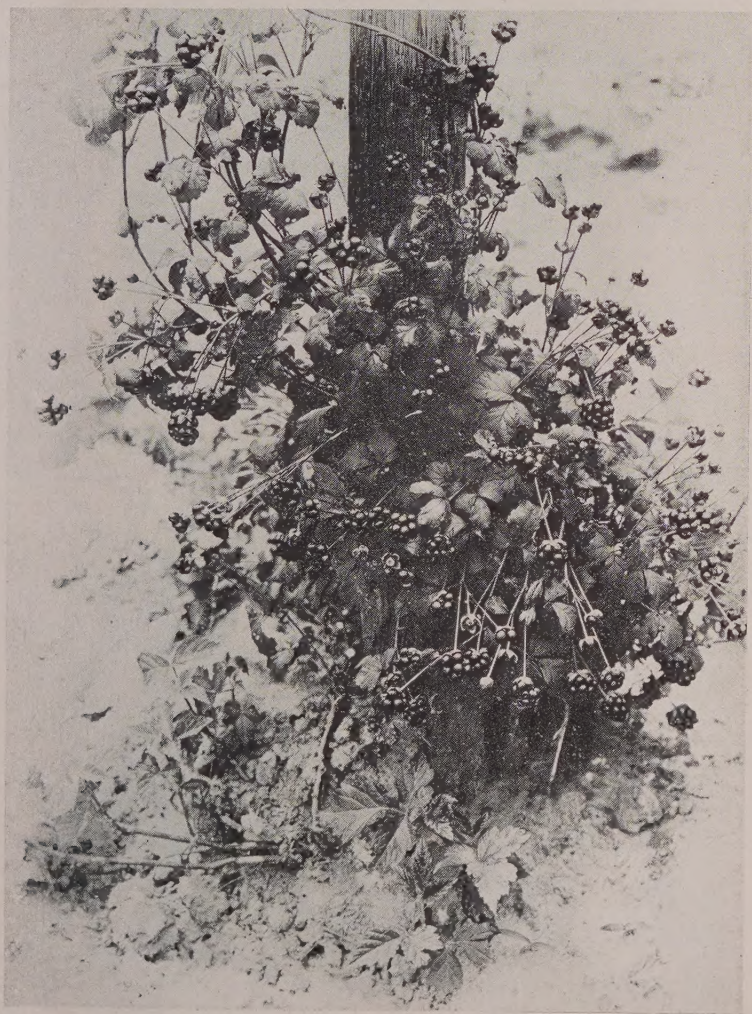


FIG. 1.—Premo, a self-sterile variety, produces a crop of nubbins when supplied with an insufficient amount of acceptable pollen.

The relative number of flowers inclosed in each bag depends entirely upon the species to which the respective varieties belong. Generally speaking, the flower clusters of *Rubus villosus* have relatively large numbers of flower buds, while those of *R. trivialis* usually possess from one to three.

By covering the flower clusters before any of the buds had opened or immediately after the careful removal of such as had opened, thus preventing all foreign pollen from gaining access to the flowers within, the potency of the pollen within the imprisoned flowers was tested. The flower clusters of each variety were covered during the forepart of their respective blooming periods, and to insure a length of time sufficient for fertilization to manifest itself the bags were not removed until it became evident to the most casual observer whether a fruit had or had not been formed. When the bags were removed a careful study of the inclosed fruits was made and the data recorded.

RESULTS AND DISCUSSION.

Dewberries.—The self-sterility work with the dewberries began with the planting of the varieties in the spring of 1908, and was finally completed in 1915, thus retaining the plants under observation for a sufficient number of years to warrant conclusions.



FIG. 2.—A fruiting branch of Manatee (dewberry.)

The results of the self-sterility test are set forth in the following table:

TABLE No. 1

DEWBERRIES.

Variety	Species	Number of Bags Recovered	Bags with Perfect Fruits	Bags with Imperfect Fruits	Bags with No Fruits
Austin.....	Villosus.....	75	74	1	0
Chestnut.....	Trivialis.....	55	0	3	52
Cox.....	Hybrid.....	38	34	1	3
Ruth.....	Hybrid.....	27	26	1	0
Grandee.....	Trivialis.....	31	0	10	1
Limekiln.....	Trivialis.....	37	0	0	37
Lucretia.....	Villosus.....	30	28	2	0
Haupt.....	Hybrid.....	30	0	2	28
Manatee.....	Trivialis.....	71	0	20	51
Munroe.....	Trivialis.....	32	0	0	32
Premo.....	Villosus.....	56	0	0	56
Elijah, No. 2.....	Trivialis.....	23	0	0	23
Rogers.....	Trivialis.....	44	1	8	36
San Jacinto.....	Trivialis.....	58	0	1	57
White.....	Trivialis.....	59	0	1	58

By means of the above table we can readily group the dewberries and the hybrids (those grown as dewberries) into two well defined classes, namely, those that are self-fertile and those that generally are self-sterile.

The imperfect fruits listed with the self-fertile varieties will need no explanation, other than that untoward conditions frequently prevent the realization of an entire crop of perfect berries. But the imperfect berries listed with the otherwise self-sterile varieties need a few words of explanation. In the first place, the imperfect fruits, viewed from the point of commercial value, are negligible, for none of them were composed of more than eight drupelets and most of them averaged less than four per berry. Furthermore, of those imperfect fruits produced by self-fertile varieties there were relatively many in each bag, while of those produced by the self-sterile varieties there were relatively few, not more than one fruit in the bag in most cases.

In the case of the Rogers variety, one bag produced one perfectly well formed and fully developed fruit. Besides this, eight bags with very small nubbins were also found. This well developed fruit undoubtedly was the result of the failure of the operator to remove a bloom which had already been fertilized and had dropped its petals. This fruit was produced in the year 1909, when twelve other bags produced only two imperfect fruits. This variety was again tested in 1910 and subsequently again in 1911. Of thirty-two bags recovered, no perfect fruits and only six very imperfect ones were discovered. We can thus safely disregard this one perfect fruit; but the imperfect ones of this

and of other generally self-sterile varieties must still be accounted for. These imperfect fruits are not the result of errors in bagging, nor are they the result of defective bags, for examination disclosed no perforations through which insects might have gained access to the flowers within.

These fruits, then, are the result either of self-fertilization, parthenogenesis, or of parthenocarp.

In order to determine the real cause of the development of the imperfect fruits, three varieties, which in the self-sterility test showed the greatest development of fruits, were selected in the spring of 1915. Of the variety Manatee, thirty-four flower buds were carefully emasculated, and immediately covered with a bag so as to prevent the access of any foreign pollen. Of Rogers and Grandee, thirty buds each were selected, emasculated and carefully covered.

The prevention of self-pollination of flowers determines whether fruit production is the result of a sexual union or whether it is the result of parthenogenesis or of parthenocarp. As a check on this work, fourteen flower buds of White and ten each of Rogers and Munroe were covered when the buds showed their pink unexpanded petals. These buds not only were not emasculated, but also when the flowers opened were carefully hand pollinated with pollen of the same variety. To offset any injury that might result from the process of emasculation, five buds of these same varieties, White, Rogers, and Munroe, were carefully emasculated and later cross-pollinated with the following varieties: White with Rogers, Rogers with White, and Munroe with Chestnut.

The results of the experiment were as follows:

TABLE No. 2

Manatee.....	34 buds, emasculated and bagged.....	No fruits set.
Rogers.....	30 buds, emasculated and bagged.....	No fruits set.
Grandee.....	30 buds, emasculated and bagged.....	No fruits set.
White.....	14 buds, not emasculated and pollinated.....	6 nubbins, 8 no fruits.
Rogers.....	10 buds, not emasculated and pollinated.....	6 nubbins, 4 no fruits.
Munroe.....	10 buds, not emasculated and pollinated.....	1 nubbins, 9 no fruits.
White.....	4 buds, emasculated and crossed.....	4 good fruits.
Rogers.....	3 buds, emasculated and crossed.....	No fruits.
Munroe.....	3 buds, emasculated and crossed.....	3 good fruits.

From the above table we note that not one of the flower buds that were emasculated and not pollinated showed any evidence of fruit formation. This fact becomes interesting in that it at once eliminates the two points under consideration, viz., parthenogenesis and parthenocarp. Hence we are led to believe that the small nubbins of berries that we found in the bags to which no foreign pollen has been admitted are the result of a sexual union of elements from the same flower. In short, some few ovules in these otherwise self-sterile varieties of dewberries will

under certain conditions accept pollen from the same flower or from flowers of the same variety.

Of the flowers that were allowed pollen from the same flower and flowers of the same variety we find that, in the case of White, out of fourteen flowers inclosed, six produced fruit composed of a few drupelets, and eight remained absolutely unaffected. The number of drupelets that were produced by the flowers varied from one to five. Of the ten flowers of Rogers, six developed a few drupelets and four developed none; while of the ten flowers of Munroe, only one flower developed a few drupelets and nine absolutely refused the pollen.

That the injury done to flowers in the emasculation process, if carefully done, is negligible and does not affect the fruit formation is seen in the last part of the table where fruit buds of White were emasculated and crossed with pollen from the variety Rogers. Each of the four flowers that were emasculated and then cross-pollinated set and developed a normal good-sized berry. The three buds of Munroe that were treated in similar manner and then cross-pollinated with pollen from the variety of Chestnut also developed berries, normal in every respect. The three buds of Rogers that were emasculated and crossed with pollen from White produced no fruits. This result at first glance would indicate a positive reaction to emasculation injury, but a careful examination of the flower remains indicated that the trouble lay with the pollen rather than with the treated flower.

All these results seem to point toward the fact that a few individual pistils of flowers of these otherwise self-sterile varieties will accept some pollen from the same flower in order to effect fertilization. With these self-sterile varieties, this phenomenon seems to be the sole remaining sexual means of perpetuation of the species in case of isolation.

With this explanation as to the cause of imperfect fruits, we get a better understanding of the real significance of the data in Table No. 1.

The varieties of dewberries then can be grouped into self-fertile and practically self-sterile classes, which are as follows: as self-fertile, we list the varieties, Austin, Cox, Ruth, and Lucretia; as self-sterile, Chestnut, Grandee, Limekiln, Haupt, Manatee, Munroe, Premo, Elijah No. 2, Rogers, San Jacinto, and White.

If now we turn to the column of species, we shall discover that all of the varieties that are self-sterile, with only two exceptions, fall into the species *Rubus trivialis*. It will be noticed that this species contains no self-fertile varieties, and this is a good indication that the species itself is self-sterile. The two self-sterile varieties that are not classified with this species are Haupt (a hybrid) and Premo, the only self-sterile variety of the species *Rubus villosus* that we are growing.

Of the self-fertile varieties, Cox and Ruth are hybrids, and Austin and Lucretia belong to the species *Rubus villosus*.

Growers of dewberries might well take more than a passing notice of this fact of sterility in dewberries, and make ample provision for cross-pollination of varieties to insure a bountiful crop of fruit.

Blackberries.—The self-sterility work with the blackberries began in the spring of 1910 and was continued through three successive seasons, ending with the year 1913. The tabulated results give a pretty clear idea as to which varieties are self-fertile and which are self-sterile.

TABLE No. 3
BLACKBERRIES.

Variety	Number of Bags Recovered	Bags with Perfect Fruits	Bags with Imperfect Fruits	Bags with No Fruits
Blowers.....	41	38	3	0
Dallas.....	39	32	6	1
E. Cluster.....	34	33	1	0
E. Harvest.....	39	39	0	0
Eldorado.....	32	32	0	0
Illinois.....	31	30	1	0
Kenoyer.....	21	15	2	4
King.....	31	30	1	0
McDonald (hybrid).....	45	0	0	45
McSereau.....	31	31	0	0
Minnewaski.....	31	29	2	0
Rathbun (hybrid).....	181	41	85	55
Snyder.....	50	28	0	2
Sorsby (hybrid).....	28	0	0	28
Spalding (hybrid).....	40	0	0	40
Wilson (hybrid).....	41	40	0	1

Upon examination of the tabulated results, obtained under the same identical conditions of control as in the case of the dewberries, namely, the absolute exclusion of all foreign pollen from the bagged clusters, we notice that nearly all of the varieties are self-fertile, that one is imperfectly self-fertile, and that three are absolutely self-sterile.

Among the self-sterile varieties are Spalding, Sorsby, and McDonald; all three of which are hybrids between blackberries and dewberries. The imperfectly self-fertile variety, Rathbun, we also find to be a hybrid. All the rest of the varieties that are mentioned above are true blackberries and are self-fertile.

It may be said by way of explanation that in the above table those bags of blackberries that are listed as containing imperfect fruits differ essentially from similarly listed bags in the case of the dewberries in Table No. 1. The difference consists in the fact that in the case of the former the bags contained whole clusters of fruits which, although imperfect, were oftentimes large enough to be utilized in the harvesting and marketing of a crop. In the case of the dewberries, however, the bags contained fruits which, in number, averaged less than 10 per cent

of the total number of flowers inclosed, and whatever fruit was in evidence was composed of only a few (one to eight) drupelets.

Even from the commercial standpoint, that variety which produced large numbers of imperfect fruits, as recorded in Table No. 3, cannot be classified with those which produced no fruit whatever, and therefore must be classified as being only imperfectly self-fertile.

By an examination of the records of the hybrids in Table No. 1, and in Table No. 2, we notice the interesting fact that among them fertility ranges all the way from absolute self-sterility, as in the case of McDonald, Sorsby, Spalding, and Haupt, through partial sterility, as in the case of Rathbun, up to complete self-fertility, as is found in the varieties of Cox, Ruth, and Wilson.

Sterility, from the evidence at hand, apparently occurs only in dewberries and their hybrids. Its cause, therefore, must be studied with the aid of dewberry and hybrid material. Blackberry varieties will henceforth in this bulletin be considered only in their relation as pollinators for the berry plantation.

THE PROBABLE CAUSE OF STERILITY.

Having determined the fact that some of our varieties of blackberry-dewberry and dewberry-blackberry hybrids, and some of our true dewberry varieties, are self-sterile, we shall now proceed to investigate the cause or the causes that might be responsible for this phenomenon of sterility.

THEORIES ADVANCED.

The investigations as to the causes of sterility will proceed along eight lines, or theories, which may be advanced as an explanation of this phenomenon. These eight theories may be stated as follows:

1. The factor of the origin of the varieties.
2. The structure of the flower, and disease (Double Blossom).
3. The daily blooming period of varieties.
4. The amount of pollen produced by the flower.
5. The factors of environment.
6. Sterility due to hybridism.
7. The percentage of defective pollen grains produced.
8. Natural antipathy between the pistils and the pollen of the same variety.

EXPERIMENTAL EVIDENCE AND DISCUSSION.

Origin of Varieties.—From our results secured on the self-sterility and the self-fertility of varieties of dewberries, the fact becomes quite clear that the ancestral species of our cultivated varieties of dewberries fall into two well defined groups, namely, those that are self-sterile and those that generally are self fertile. The tabulated data in Table No. 1 reveals the fact that all of the varieties that are pure lineal descendants

of *Rubus trivialis*, and those varieties in which *trivialis* blood predominates, are self-sterile, while those varieties that come from *Rubus villosus* generally are self-fertile. Of this last named species, two varieties, Premo and Rathbun, prove to be exceptions under our observation. Premo exhibits absolute self-sterility, while Rathbun (a hybrid) is only partially self-fertile.

However, with only two varieties of *Rubus villosus* proving to be positively self-fertile, and one decidedly self-sterile, it was deemed expedient to test the species at large, that is, the wild species, before making any generalizations.

Rubus villosus is indigenous to our soil and climate, and the vines are to be found growing profusely and abundantly in and about our fields and woods. Accordingly, in the spring of 1915 twenty individual wild vines were marked, and on April 20th five clusters of flower buds on each of the vines were covered with cloth and paper bags.

If the species be self-sterile, we would find no fruits in the bags during the fruiting season; if the species be self-fertile, then we should expect to see a crop of berries in each of the undisturbed bags; if the species be composed of both self-fertile and self-sterile vines, then we should expect to get varying results. The following table shows the results of this test:

TABLE No. 4

Number of Vine	Species	Number of Bags Recovered	Number of Fruits	Number Without Fruits
No. 1.....	Villosus.....	4	4	0
No. 2.....	Villosus.....	4	2	2
No. 3.....	Villosus.....	4	3	1
No. 4.....	Villosus.....	1	0	1
No. 5.....	Villosus.....	5	0	5
No. 6.....	Villosus.....	5	4	1
No. 7.....	Villosus.....	3	2	1
No. 8.....	Villosus.....	5	4	1
No. 9.....	Villosus.....	4	2	2
No. 10.....	Villosus.....	9	9	0
No. 11.....	Villosus.....	10	10	0
No. 12.....	Villosus.....	9	9	0
No. 13.....	Villosus.....	5	5	0
No. 14.....	Villosus.....	7	6	1
No. 15.....	Villosus.....	11	11	0
No. 16.....	Villosus.....	14	3	11
No. 17.....	Villosus.....	4	4	0
No. 18.....	Villosus.....	5	4	1
No. 19.....	Villosus.....	5	5	0
No. 20.....	Villosus.....	5	5	0

From the tabulated results, the fact stands out very clearly that the species *Rubus villosus* at large is quite self-fertile. From this it is evident that the case of the variety Premo is simply an exception to the general rule, and requires special investigation.

It will be noticed that vines Nos. 4 and 5 record absolute self-sterility; but this sterility is undoubtedly due to the fact that the flower buds of these vines were far too small when they were inclosed. The same may be said about most if not all of the other buds that proved to be self-sterile. The proper time to inclose the buds is when the pink shows well on the expanding petals, and about one or two days before the bud may be expected to open.



FIG. 3.—Flowers of Manatee (dewberry) showing good cases of petalody.

Knowing, then, that the parental species of our cultivated varieties of dewberries are either self fertile or self sterile, we should anticipate finding similar characteristics respectively in the daughter vines, and with few exceptions such is the case.

The Structure of the Flower and Disease.—Petalody in the genus *Rubus* is by no means an unusual phenomenon, but when it occurs to such an extent and to such a high degree of development that it may endanger the normal functions of the essential organs of the flower,

then it becomes a vital factor in fruit production. This numerical increase in number of petals has developed to an unusual and to a very marked degree in the case of the variety Manatee.

Each of the plants of this variety was examined as to petalization, and each was found to produce blooms with both a normal and an abnormal number of petals. As the normal number of petals for the genus *Rubus* is five, any flower with more petals was considered petaliferous. The actual number of petals ranged all the way from five to twelve and fifteen. This condition of petalody is not peculiar to the variety Manatee, except in degree. Many other varieties are more or less affected, and notable among these are Chestnut and Elijah No. 2. Some of the flowers of Manatee are often so double as to resemble a small pink rose. In some years this abnormal condition of the bloom is much more pronounced than in others.

When many flowers of Manatee are bagged and allowed to be self-pollinated, we observe that frequently among them some will develop and bring to maturity a small number of drupelets. This phenomenon has been observed in such other varieties as Chestnut, Grandee, Haupt, Rogers, and to a very limited extent in San Jacinto and in White.

When Manatee is cross-pollinated with other varieties of dewberries, fruits will develop, but the berries are very rarely perfect and well formed.

The reason that these berries seldom develop normally may be attributed to climatic or to soil conditions, for in Florida, where Manatee originated, the vines are said to produce an abundance of well formed fruits.

In order to ascertain whether Manatee is sterile because the extra number of petals really hindered pollen from reaching the stigmas of the pistils, five flower buds were bagged and pollen from Manatee flowers was artificially applied. Later, upon examination of these inclosed flowers, it was discovered that no fruits had set. The complete record of results follows:

TABLE No. 5

Number of Bags	Number of Flowers	Number of Perfect Fruits	Number of Nubbins	Number Sterile
No. 1.....	1	0	0	1
No. 2.....	1	0	0	1
No. 3.....	1	0	0	1
No. 4.....	1	0	0	1
No. 5.....	1	0	0	1

The results in the above table indicate that the excessive number of petals in the dewberry flowers does not necessarily constitute a mechanical obstruction to the process of pollination, but that Manatee is self-

sterile, notwithstanding the fact that its flowers frequently have an excessive number of petals.

If we carefully examine the flowers of our cultivated varieties of dewberries and hybrid blackberries we notice that two varieties, viz., Premo and Rathbun, show irregularities in the formation of their stamens. The flower buds of Premo are different from those of most other varieties of dewberries and blackberries in that the pistils rapidly elongate and protrude from the flower buds several days before the



FIG. 4.—Flower clusters of Premo (dewberry), showing how the pistils protrude from the bursting flower buds.

petals expand, and before the stamens mature. This apparently is a provision for securing cross-pollination.

Also, very often the stamens of the flowers are defective. Many of them never develop beyond mere rudimentary organs, some partly develop, others have their filaments dwarfed, and still others develop normal filaments but with anther sacs that are diseased and which liberate only defective or aborted pollen. The remaining stamens apparently produce normal pollen, but fruit will not set when the flowers are self-pollinated.

The flower of Rathbun is very similar to that of Premo except that the pistils do not protrude from the flower bud. When Rathbun flowers are self-pollinated we usually get some fruit development, and this fruit may range all the way from almost perfect to no fruit at all.

In regard to the question of self-sterility of varieties of dewberries, however, the fact still remains that in many other varieties with healthy normal stamens, complete self-sterility exists. Hence, another solution of the question of sterility must be sought.

Petalody in normal plants must not be confused in any way with Double Blossom (34th Ann. Rept. N. C. Agr. Exp. Sta., 1912, by



FIG. 5.—Flowers of Rathbun, (blackberry-dewberry hybrid), showing very much weakened and reduced stamens.

Reimer and Detjen and De; Agr. Exp. Sta. Bul. No. 93, by M. T. Cook), which is a disease that is caused by a parasitic fungus, *Fusarium rubi* (Winter).

This fungus is frequently the cause of the development of unusually large numbers of petals in the flowers of some varieties, notably, Lucretia and Wilson. In fact, some of the affected blooms quite resemble a small white double rose.

The real difference between a petaliferous bloom of a normal plant and a petaliferous bloom of one that is affected with *Fusarium rubi* is revealed in the production of fruit. Petaliferous flowers on otherwise

normal plants, when cross-pollinated with self-fertile varieties, very frequently set normal berries, while those petaliferous blooms which are the direct result of the action of fusarium very seldom if ever set fruit. The reason for this can be attributed to the destruction by the fungus of the essential organs in the flowers.

Sometimes, as in the case of the variety Manatee when cross-pollinated with pollen from self-sterile varieties, only nubbins are produced; however, this phenomenon is explained elsewhere in this bulletin, and will not be discussed at this point.

"Double Blossom" is not always revealed by the phenomenon of petalization. Many flowers that are apparently normal never set any fruit. In such cases only the sexual organs have been affected by fusarium, and consequently no fruit was produced. Careful examination of the flowers of all of our varieties that are affected with sterility, however, revealed only a very few traces of the disease.

The Daily Blooming Period.—In searching for the underlying cause of sterility in dewberries, it was deemed advisable to investigate the daily blooming period, and the relative time of dehiscence of the anther sacks. Flowers of *Rubus villosus* were observed opening at different times, some in the morning hours, some at noon, and still others in the afternoon. In fact, flowers in all stages of opening could be observed during all times of the day, depending, of course, upon the conditions of the weather.

Flowers of the different varieties of *Rubus trivialis* were observed to behave in a very similar fashion to those of *R. villosus*; hence the daily blooming periods of the two species, in this respect, are quite similar.

The anthers also were investigated as to the time of their dehiscence. It was found that in neither case did all of the anthers dehisce at the same time. Anthers sometimes burst before the petals expand, but in the majority of cases dehiscence begins after the flower has fully opened. The outer cycle of stamens first begins to shed its pollen, and the other or inner cycles follow in the order of their maturity. Generally speaking, twelve to twenty-four hours elapse before the last anther in the flowers has burst.

Because of this continuous shedding, a scarcity of pollen cannot be held responsible for the nonsetting of fruits, because any insect visiting such flowers cannot fail to become coated all over with the powdery element and transfer the same to other flowers.

Both species of dewberries were carefully observed in this respect, and as no difference in their behavior was found, we were forced to conclude that the daily blooming period and the time of the shedding of pollen has no effect on the general question of sterility.

The Amount of Pollen Produced.—By comparing the flowers of the self-fertile varieties with those of the self-sterile varieties, we observe at a glance that, with a few exceptions, the former produce far more pollen than the latter. This fact at once raises the question, Does the

small amount of pollen that is produced by some varieties account for the nonsetting of fruit?

In Table No. 6 is found the answer to this question. Pollen carefully gathered from the self-sterile varieties was actually applied by hand to the pistils of flowers of the same varieties, and no fruit was obtained. Therefore, the insufficiency of pollen production does not account for the absolute sterility of any variety of dewberries or of their hybrids.



FIG. 6.—Flowers of Lucretia (dewberry), showing well developed stamens.

However, in the growing of berry crops for commercial purposes we must bear in mind that the factor of pollen production is an important item. Insufficiency of pollen under these conditions may be the real cause of a crop failure, even although it will not account for the self-sterility of the variety. Because not enough of pollen is produced to satisfy the requirements of the pistils in all of the flowers of the whole field, the resultant crop is not only reduced in size, but also in quality, for the individual berries have suffered because a certain percentage

of its ovules did not receive the proper amount of pollen that is required for complete fertilization. Hence a large number of nubbins are produced instead of the well developed berries. The real cause of sterility, however, has not yet been reached.

Sterility Due to Environmental Conditions.—It is a fact that trees and plants which are generally self-fertile, under normal conditions, will produce an abundance of fruit, but which when subjected to abnormal conditions, such as a superfluity of moisture, an abnormal amount of nitrogen in the soil, late spring frosts, etc., will forego the production of fruit. In order to forestall any influences that might find their origin in the environs of the plants under our observation, the test plants in our experimental field were laid out in the following manner:

A square field, having approximately an area of two and one-half acres, was divided into two nearly equal parts, the division line extending from west to east. The northern half was devoted entirely to blackberries and blackberry-dewberry hybrids, and the southern half to dewberries and dewberry blackberry hybrids. Each half of the field was further subdivided into equal sized plats sufficiently large to accommodate three rows of each of the varieties with thirty plants to the row. The plants and the rows lie in a north and south direction. The distances between the plants in the rows, the rows from one another, and the spaces between the separate plants were made equal and uniformly at five feet. The whole field was laid off on the square system. Thus, the whole collection of test plats has the appearance of a regular fruit plantation. No especial care was exercised in the selection of varieties which were to occupy the successive plats of the plantation; however, it so happened, as was later discovered, that the self-fertile and the self-sterile varieties were pretty well mingled.

The square system of planting made possible the uniform cultivation of the individual plants in both directions, and made impossible unconscious differences in the treatment of the individual plats.

The soil of this berry plantation is a sandy loam underlaid with a clay subsoil and is as nearly uniform as it was possible to secure. Fertilizers were applied semiannually to the plantation as a whole, the phosphates and potash predominating in the spring application and the nitrogen element predominating in the summer application.

The cultivation of the individual plats consisted in the cultivation of the plantation as a whole; clean culture in the spring and summer, and a cover crop of rye or of cowpeas in the fall and winter. Thus the soil treatment accorded to one plat was accorded to all, and therefore the environment of one variety became, as nearly as was possible to make it, the environment of each and all other varieties.

If, then, the environment be the cause of the sterility of the different varieties, we should anticipate either sterility in all of the varieties or no sterility in any of them. It might be contended, however, that the conditions to which all of these varieties were subjected might be more

detrimental to some species or varieties than to others, and that for this reason varieties might behave differently. Allowing due credit for this fact, we nevertheless find that under normal conditions, and with varieties interplanted for cross-pollination, we get normal crops of fruit from all with the exception of Manatee. This fact is sufficient evidence that soil and soil-fertility factors must be separated and eliminated from the real causes that underlie the phenomenon of sterility of varieties in dewberries and dewberry hybrids.

Another factor of environment, namely, that of late spring frosts, must here be considered, because in this case the different varieties are not similarly affected. Some varieties of dewberries and hybrids are more susceptible to cold than are some others.

Late spring frosts may destroy a berry crop in two different ways: first, by killing outright the succulent growth of vines that begin activity of growth during the early warm spells of late winter; and second, by the injury of the blooms of early flowering varieties. The crop of blooms for the season being destroyed, but very little fruit from such varieties can be expected during the following season.

Although all of the varieties of dewberries that have their origin in *Rubus trivialis* (and also the four hybrid varieties, Haupt, Sorsby, Spalding, and McDonald, which, from evidence derived from Table No. 1 prove to be self-fertile) belong to this group of early growers, and although it frequently happens that in this locality, as well as elsewhere, these varieties frequently have their crop of fruit considerably diminished by late spring frosts, the fact yet remains that during normal years these same varieties bring forth a bountiful supply of fruits. Thus, late spring frosts cannot be regarded as the cause of the general sterility of dewberries and their hybrid varieties.

Sterility Due to Hybridism.—That the mating of two widely separated species of plants or of animals frequently produces sterility in the offspring is a recognized fact. As an example, Dr. Peter Wylie in his report on the breeding of grapes wrote as follows: "We can impregnate the foreign (*Vitis vinifera*) with pollen from the Scruppernong, producing thereby only male (staminate) plants and imperfect hermaphrodite or pistillate plants, which bear no fruit." Again, all of Rogers' hybrids which are the offspring of native species of grapes crossed with pollen from *Vitis vinifera* are with only one exception self-sterile.

Any investigation as to the sterility of any variety of plants would be incomplete if it omitted altogether this important factor of ancestry.

By investigating the botanical characters of our cultivated varieties of dewberries we arrive at certain definite conclusions: First, that most of our cultivated varieties of dewberries, as near as we can ascertain, are direct lineal descendants from native species, and that but few are hybrids. Second, that generally the direct descendants of these native species retain the same relationship to the question of fertility exhibited by the parental species. An exception to this rule is found in the case

of the variety Premo, which presumably is a direct descendant from the self-fertile species *Rubus villosus*. Third, that true hybrids between self-fertile species of *Rubus* (examples of which are the varieties Cox, Ruth, and Wilson) may retain complete self-fertility, but sometimes only partial self-fertility, as in the case of Rathbun. Fourth, that true hybrids of *Rubus* species with self-sterile species may be self-sterile, examples of which are Haupt, Spalding, Sorsby, and possibly McDonald.

These hybrids are not self-sterile, however, because of the fact that they are of hybrid origin, but, rather, because sterility was imparted to them directly by one of their parents, presumably some variety of *Rubus trivialis*.

Since some of the varieties of true dewberries which show no hybrid origin are utterly incapable of setting fruit by themselves, we conclude that the true cause for the sterility of the dewberries and their hybrids must be sought elsewhere.

Amount of Defective Pollen (Microscopical Test)

TABLE NO. 6

PERCENTAGE OF NORMAL POLLEN GRAINS.

Variety	Species	Count Number 1	Count Number 2	Count Number 3
		<i>Per Cent.</i>	<i>Per Cent.</i>	<i>Per Cent.</i>
Austin.....	<i>R. villosus</i>	92.1	95.9	95.6
Chestnut.....	<i>R. trivialis</i>	73.5	77.9	83.7
Cox.....	Hybrid.....	78.6	76.8	83.7
Ruth.....	Hybrid.....		74.6	82.4
Grandee.....	<i>R. trivialis</i>	41.2	69.6	51.1
Limekiln.....	<i>R. trivialis</i>	93.4	92.0	91.3
Lucretia.....	<i>R. villosus</i>		92.7	95.8
Haupt.....	Hybrid.....	38.2	77.4	82.9
Manatee.....	<i>R. trivialis</i>	95.9	39.7	36.8
Munroe.....	<i>R. trivialis</i>	96.5	96.3	96.5
Premo.....	<i>R. villosus</i>		94.8	94.5
Elijah, No. 2.....	<i>R. trivialis</i>	78.0	96.3	93.2
Rogers.....	<i>R. trivialis</i>	94.5	91.9	92.5
San Jacinto.....	<i>R. trivialis</i>	68.9	79.6	91.7
White.....	<i>R. trivialis</i>	95.2	96.4	92.8
Spalding.....	Hybrid.....			56.4
Rathbun.....	Hybrid.....			57.5
McDonald.....	Hybrid.....			59.5
Sorsby.....	Hybrid.....			76.3
Wilson.....	Hybrid.....			53.2

The method used to secure the data in the above table was as follows: ten normal flowers, selected quite at random from different plants of the same variety, were used to supply the representative samples of pollen. The pollen from the ten flowers was shaken into a glass vial, thoroughly mixed by mechanical means, and then subjected to a microscopical examination. This examination consisted in counting and record-

ing of the total number of apparently perfect and the total number of defective pollen grains that were found in ten separate fields under the microscope. From these figures the percentages of good and of defective pollen grains were calculated.

This method of procedure was repeated for each variety, and the condition of its pollen determined. It must be stated that pollen grains which appeared normal regardless of actual viability were classed as good grains, and only small, hollow, and shriveled grains were counted as defective. With some varieties this distinction becomes somewhat difficult because of the production of a great many angular grains which closely resemble the defective ones.

From the tables we learn some interesting facts: first, that the self-sterile varieties of *Rubus villosus* produce a comparatively high (over 90%) percentage of normal pollen grains, and that Premo, the only lineal descendant grown here which does not produce such a quantity of normal pollen, is self-sterile; second, that the other self-sterile varieties, all of which, with the exception of the hybrids, are representative varieties of *Rubus trivialis*, vary considerably in the amount of defective pollen that they produce. Such varieties as Limekiln, Munroe, Rogers, and White produce a very small percentage of defective pollen, less than 8 per cent. In this respect they correspond very favorably with those varieties that are of *Villosus* origin and which are self-fertile. Other varieties of this same species, such as Chestnut, Manatee, and San Jacinto, show a very much larger per cent of defective pollen. With the exception of Manatee, these varieties produce approximately from 50 to 80 per cent of normal pollen. Manatee falls far below this class in that it sometimes produces as high as sixty and three-tenths (60.3) per cent and sometimes as high as ninety-four and one-tenth (94.1) per cent of defective pollen. All of these varieties are self-sterile. Cox and Ruth, two self-fertile varieties of hybrid origin, while perfectly self-fertile, produce as high as approximately twenty-two and three-tenths (22.3) per cent and twenty-five and four-tenths (25.4) per cent of defective pollen grains; while Haupt, a hybrid, which also produces an equally large amount of perfect pollen, is self-sterile.

From these results it becomes quite evident that the quantity or the number of defective pollen grains in the flowers of our self-sterile varieties of dewberries and hybrids plays no fundamental role in the cause of self-sterility of such varieties. The production of a comparatively high or a comparatively low percentage of defective pollen grains, however, becomes of vital importance to the commercial fruit grower in the selection of pollinators for the berry plantation. For, other conditions being equal, the greater the per cent of pollen produced, the greater are the chances for perfect cross-pollination and a "bumper" crop. The subject of the commercial importance of varieties which habitually produce a high per cent of perfect pollen will be discussed later under the subject of pollinators for the plantation.

Germination Test of Pollen.—Having discovered that self-sterile varieties of dewberries produce an abundance and in some cases, as high a percentage of morphologically normal pollen grains as any of those varieties that are self-fertile, the question of the viability of these apparently normal grains becomes of prime importance.

Pollen was gathered from all of the varieties, and subjected to a germination test in the laboratory by means of "hanging-drop" slides and germination solutions. The culture medium, as was discovered, might consist of either weak sugar solutions of varying strength, tap water, or even distilled water. Ordinary tap water was as good as any, and less troublesome to secure.

All of the examined slides disclosed the fact that the pollen grains which morphologically appeared normal were capable of a vigorous germination and growth, and that the self-sterility of varieties of dewberries is not caused by morphological defectiveness or a lack of viability in the pollen grains. Sterility has its seat in a more remote cause and requires further investigation.

Natural Antipathy Between Pistils and Pollen from the Same Variety.—Because self-sterile varieties of dewberries and their hybrids will, under normal conditions for cross-pollination, set an abundance of fruit, the fact is quite patent that the morphology of the pistils (stigma, style, and ovary) is quite normal, and apparently offers no explanation of the phenomenon of sterility. From the foregoing recorded results in regard to the viability of pollen from self-sterile varieties, and also from the good fruit crops secured under ordinary field conditions, we naturally draw the conclusion that the viability of the pollen grains is not responsible for the sterility of the variety. All of the essential organs of the flowers under certain conditions seem to function normally, and yet this phenomenon, self-sterility, does exist.

Whether in the case of self-pollination the pollen functions normally and the pistil behaves abnormally, or *vice versa*, or whether both organs refuse to act, has not been determined. At any rate, the antipathy between the pistil and pollen of the same variety seems to be the immediate cause for the failure of fruit setting, and therefore of self sterility.

What this rather vague term, natural antipathy, really signifies—whether it is due to a toxic substance located in the pollen grain in the stigmatic secretions, style, or the ovules—remains yet to be discovered.

Viable pollen grains from a self-sterile variety, although ineffective on the pistils of flowers of the same variety, will bring about perfect fertilization when placed on the stigmas of another variety; and it matters little whether this second variety be self-fertile or self-sterile, of the same species or of another species (*Rubus villosus*).

The following table shows the results of extensive cross-pollination tests:

DEWBERRIES AND HYBRIDS.

Variety	Cross-pollinator	Number of Bags Recovered	Bags with Perfect Fruits	Bags with Imperfect Fruits	Bags with No Fruits
1911—					
White.....	San Jacinto.....	4	4	0	0
	Munroe.....	5	5	0	0
	Chestnut.....	6	6	0	0
	Limekiln.....	4	4	0	0
	Rogers.....	5	5	0	0
	Manatee.....	2	1	1	0
Limekiln.....	White.....	5	5	0	0
	San Jacinto ..	5	5	0	0
	Chestnut.....	5	5	0	0
	Manatee.....	5	3	1	1
	Rogers.....	5	5	0	0
	Munroe.....	5	5	0	0
Munroe.....	White.....	5	5	0	0
	San Jacinto.....	5	5	0	0
	Chestnut.....	4	4	0	0
	Limekiln.....	4	4	0	0
	Rogers.....	3	3	0	0
	Manatee.....	5	4	1	0
San Jacinto	White.....	4	4	0	0
	Munroe.....	5	5	0	0
	Chestnut	4	4	0	0
	Limekiln.....	5	5	0	0
	Rogers.....	4	4	0	0
	Manatee.....	5	5	0	0
Chestnut.....	White.....	5	5	0	0
	San Jacinto.....	4	4	0	0
	Munroe.....	4	4	0	0
	Limekiln.....	5	5	0	0
	Rogers.....	5	5	0	0
	Manatee.....	4	4	0	0
Rogers.....	White.....	4	4	0	0
	San Jacinto ..	4	4	0	0
	Munroe.....	5	5	0	0
	Chestnut	5	5	0	0
	Limekiln.....	5	5	0	0
	Manatee.....	3	3	0	0
Manatee	White.....	5	2	0	3
	San Jacinto.....	5	0	0	5
	Rogers.....	4	0	0	4
	Limekiln.....	3	0	1	2
	Munroe.....	5	0	1	4
	Chestnut	4	1	0	3
1912—					
Manatee.....	White.....	5	1	0	4
	San Jacinto.....	5	0	0	5
	Rogers.....	3	0	0	3
	Limekiln.....	4	0	0	4
	Munroe.....	5	0	0	5
	Chestnut.....	4	0	1	3
	Haupt.....	5	0	2	3
	Grande.....	5	0	2	3
	Lucretia.....	8	8	0	0
	Cox.....	5	5	0	0
	Ruth.....	4	4	0	0

DEWBERRIES AND HYBRIDS—CONTINUED.

Variety	Cross-pollinator	Number of Bags Recovered	Bags with Perfect Fruits	Bags with Imperfect Fruits	Bags with No Fruits
1915—					
San Jacinto.....	Lucretia.....	2	2	0	0
	Elijah, No. 2....	2	2	0	0
	Haupt.....	2	2	0	0
	Grandee.....	1	1	0	0
	Ruth.....	2	2	0	0
	Cox.....	2	2	0	0
	Austin.....	2	2	0	0
	Manatee.....	2	0	2	0
Rogers.....	Check.....	1	0	1	0
	Chestnut.....	1	1	0	0
	Lucretia.....	2	2	0	0
	Elijah, No. 2....	2	1	0	1
	Grandee.....	2	2	0	0
	Ruth.....	2	2	0	0
	Manatee.....	2	0	2	0
	Cox.....	2	2	0	0
Elijah, No. 2....	Austin.....	2	2	0	0
	Check.....	2	0	2	0
	Lucretia.....	2	2	0	0
	White.....	2	2	0	0
	San Jacinto.....	2	2	0	0
	Rogers.....	2	2	0	0
	Premo.....	2	0	2	0
	Munroe.....	2	2	0	0
Manatee.....	Manatee.....	2	0	2	0
	Haupt.....	2	2	0	0
	Limekiln.....	2	2	0	0
	Grandee.....	2	2	0	0
	Ruth.....	2	2	0	0
	Cox.....	2	2	0	0
	Chestnut.....	2	2	0	0
	Austin.....	2	2	0	0
Munroe.....	Check.....	2	0	0	2
	Lucretia.....	1	1	0	0
	White.....	2	0	0	2
	San Jacinto.....	2	0	0	2
	Rogers.....	1	0	0	1
	Elijah, No. 2....	2	0	1	1
	Premo.....	2	0	2	0
	Munroe.....	2	0	0	2
Munroe.....	Haupt.....	1	1	0	0
	Limekiln.....	2	0	0	2
	Grandee.....	2	0	1	1
	Ruth.....	2	2	0	0
	Cox.....	2	1	1	0
	Chestnut.....	2	0	1	1
	Austin.....	2	1	1	0
	Check.....	2	0	0	2
Munroe.....	Lucretia.....	2	2	0	0
	Elijah, No. 2....	2	2	0	0
	Haupt.....	2	1	1	0
	Grandee.....	2	1	0	1
	Ruth.....	2	2	0	0
	Cox.....	2	2	0	0
	Austin.....	2	2	0	0
	Check.....	2	0	0	2
Munroe.....	Manatee.....	2	0	2	0

DEWBERRIES AND HYBRIDS—CONTINUED.

Variety	Cross-pollinator	Number of Bags Recovered	Bags with Perfect Fruits	Bags with Imperfect Fruits	Bags with No Fruits
Haupt.....	White.....	2	2	0	0
	San Jacinto.....	2	1	0	1
	Rogers.....	2	2	0	0
	Elijah, No. 2.....	2	2	0	0
	Munroe.....	2	2	0	0
	Manatee.....	2	0	2	0
	Lucretia.....	2	2	0	0
	Limekiln.....	2	2	0	0
	Ruth.....	2	1	0	1
	Cox.....	2	2	0	0
	Chestnut.....	2	2	0	0
	Austin.....	4	4	0	0
	Check.....	2	0	0	2
	Elijah, No. 2.....	2	2	0	0
White.....	Haupt.....	2	2	0	0
	Lucretia.....	2	2	0	0
	Grandee.....	2	2	0	0
	Ruth.....	2	2	0	0
	Cox.....	2	2	0	0
	Austin.....	2	2	0	0
	Manatee.....	2	0	2	0
	Check.....	1	0	0	1
	Lucretia.....	2	2	0	0
	White.....	2	1	1	0
Grandee.....	San Jacinto.....	2	1	0	0
	Rogers.....	2	2	0	0
	Elijah, No. 2.....	2	2	0	0
	Premo.....	2	2	0	0
	Munroe.....	2	2	0	0
	Manatee.....	2	0	1	1
	Haupt.....	2	0	2	0
	Limekiln.....	2	2	0	0
	Ruth.....	2	2	0	0
	Cox.....	2	2	0	0
	Chestnut.....	1	1	0	0
	Austin.....	2	2	0	0
	Check.....	3	0	2	1
	White.....	2	0	1	1
	San Jacinto.....	2	2	0	0
	Rogers.....	2	2	0	0
	Elijah, No. 2.....	1	1	0	0
	Premo.....	2	2	0	0
	Munroe.....	2	2	0	0
Lucretia.....	Haupt.....	2	2	0	0
	Limekiln.....	2	2	0	0
	Grandee.....	2	0	2	0
	Ruth.....	2	2	0	0
	Cox.....	2	2	0	0
	Chestnut.....	2	2	0	0
	Austin.....	2	2	0	0
	Manatee.....	4	0	3	1
	Check.....	2	0	0	2
	Lucretia.....	2	2	0	0
	Elijah, No. 2.....	2	2	0	0
	Haupt.....	2	2	0	0
	Grandee.....	2	2	0	0
	Ruth.....	2	2	0	0
	Cox.....	2	2	0	0
	Chestnut.....	2	2	0	0
	Austin.....	2	2	0	0
	Manatee.....	4	0	3	1
	Check.....	2	0	0	2
Chestnut.....	Lucretia.....	2	2	0	0
	Elijah, No. 2.....	2	2	0	0
	Haupt.....	2	2	0	0
	Grandee.....	2	2	0	0
	Ruth.....	2	2	0	0
	Cox.....	2	2	0	0
	Austin.....	2	2	0	0

DEWBERRIES AND HYBRIDS—CONTINUED.

Variety	Cross-pollinator	Number of Bags Recovered	Bags with Perfect Fruits	Bags with Imperfect Fruits	Bags with No Fruits
Chestnut.....	Manatee.....	2	0	1	1
	Check.....	2	0	0	2
Austin.....	Lucretia.....	2	2	0	0
	White.....	2	1	1	0
	San Jacinto.....	2	0	2	0
	Rogers.....	2	2	0	0
	Elijah, No. 2.....	2	2	0	0
	Premo.....	2	2	0	0
	Munroe.....	2	2	0	0
	Manatee.....	2	0	1	1
	Haupt.....	2	2	0	0
	Limekiln.....	2	2	0	0
	Grandee.....	2	0	1	1
	Ruth.....	2	2	0	0
	Cox.....	2	2	0	0
	Chestnut.....	2	2	0	0
	Check.....	4	0	0	4
Cox.....	Lucretia.....	2	2	0	0
	White.....	2	2	0	0
	San Jacinto.....	2	2	0	0
	Rogers.....	2	1	0	1
	Elijah, No. 2.....	2	2	0	0
	Premo.....	2	0	0	2
	Munroe.....	2	2	0	0
	Manatee.....	2	0	0	2
	Haupt.....	2	2	0	0
	Limekiln.....	2	2	0	0
	Grandee.....	2	2	0	0
	Ruth.....	2	2	0	0
	Chestnut.....	2	2	0	0
	Austin.....	2	2	0	0
	Check.....	3	0	0	3
Premo.....	Lucretia.....	2	2	0	0
	Elijah, No. 2.....	2	2	0	0
	Manatee.....	2	1	1	0
	Haupt.....	2	2	0	0
	Limekiln.....	2	2	0	0
	Grandee.....	2	2	0	0
	Ruth.....	2	2	0	0
	Chestnut.....	2	2	0	0
	Austin.....	2	2	0	0
	Check.....	5	0	0	5
Ruth.....	Lucretia.....	2	2	0	0
	White.....	3	3	0	0
	San Jacinto.....	2	2	0	0
	Rogers.....	2	2	0	0
	Elijah, No. 2.....	2	2	0	0
	Premo.....	2	1	0	0
	Munroe.....	2	1	1	0
	Manatee.....	2	0	2	0
	Haupt.....	2	2	0	0
	Limekiln.....	2	2	0	0
	Grandee.....	2	2	0	0
	Cox.....	2	2	0	0
	Chestnut.....	2	2	0	0
	Austin.....	2	2	0	0
	Check.....	5	0	0	5
Limekiln.....	Manatee.....	2	0	1	1

From a study of the above tables we come to the following conclusions: first, that the pollen from the self-fertile varieties of *Rubus villosus* can fertilize the flowers of other self-fertile varieties of the same species; second, that the pollen from self-fertile varieties of *Rubus villosus* can fertilize the flowers of self-fertile varieties of the same species, and also, with the exception of the variety Manatee, those of the self-sterile species, *Rubus trivialis*; third, that the pollen from the self-fertile variety Premo can fertilize the self-sterile varieties of the same species, and, with the exception of Manatee, the self-fertile varieties of *Rubus trivialis*; fourth, that the self-sterile varieties of *Rubus trivialis* can fertilize all varieties of *Rubus villosus* and, with the variety Manatee excepted, the self-sterile varieties of *Rubus trivialis* and their hybrids; fifth, that the pollen from a self-sterile variety cannot fertilize the flowers of the same variety.

Consequently, the very interesting fact becomes evident that self-fertile varieties are not the only ones that can be used successfully as pollinators in a berry plantation, but that so far as viability of the pollen and fertilization is concerned, we can also use the recognized self-sterile varieties. This fact, with the exception of Manatee, holds true, even though all of the varieties that are to be pollinated are self-sterile.

The variety Manatee presents a very unique case, and requires some words of explanation. From the information gained in Table No. 1, we learn that Manatee is practically a self-sterile variety. Frequently, however, under certain conditions of self-pollination, one to several drupelets will be produced and will ripen. This condition, as has previously been stated, appears to be the result of self-fertilization. Other varieties of *Rubus trivialis* frequently behave similarly.

Manatee, when crossed with other varieties, behaves variously: generally speaking, it will not set much, if any, fruit when crossed with pollen from the self-sterile varieties of *Rubus trivialis*. When crossed with pollen from the self-fertile varieties of *Rubus villosus* some fruits will develop; but with us, Manatee growing in a mixed plantation never has set a paying crop of berries. As a pollinator for other varieties, therefore, Manatee is worthless, because the percentage of defective pollen produced by its flowers is so great that in a large berry plantation a dearth of viable pollen would be the result.

As has already been mentioned, the pollen of Manatee seems not to be very acceptable to flowers of other varieties of *Rubus trivialis*, for while in some years fairly good fruit was obtained in the hybridizing tests, yet in other seasons the resultant fruit crop was exceedingly poor, and in some cases no fruit at all was obtained. Neither is it very acceptable to varieties of *Rubus villosus*. Lucretia, Austin, Premo, and the self-fertile hybrids, Cox and Ruth, when pollinated with Manatee, show varying results. Of the varieties mentioned, Ruth seems to be able to use Manatee pollen to the best advantage, for the resultant fruit seems quite

normal in all external appearances. To sum it up, the variety Manatee has nothing to recommend it as a fruit producer, and still less as a general pollinator for other varieties.

POLLINATORS FOR THE BERRY PLANTATION

Although most of our important varieties of dewberries and blackberries are self-fertile, the crops might be considerably improved by the judicious selection of good pollinators. Pollinators not only serve to improve a crop, but, with many varieties, they are an actual necessity for the production of berries. Thus, all of the varieties that spring from the species *Rubus trivialis* need a pollinator in order to set a crop of fruit. Other varieties of dewberries are similarly affected, and the



FIG. 7.—Flower clusters of Snyder and King (blackberries), showing ample pollen production.

absence, in some cases, of a suitable pollinator practically means the total loss of a fruit crop.

Requirements of a Good Pollinator.—The requirements of a good pollinator are the following: first, self-fertility; second, a blooming period which is coincident with that of the variety to be pollinated; third, the production of an abundance of good viable pollen.

That self-fertile varieties are most desirable for pollinators becomes evident from the fact that during unfavorable weather conditions in the blooming season the flowers of such varieties are still able to set an abundance of fruit with the aid of their own pollen—they need not wait for insects to carry the pollen to them. On the other hand, with varieties not perfectly self-fertile, any condition which affects the activity of insects during the blooming season also affects the setting of fruit more or less seriously.

Dewberry and blackberry flowers differ somewhat from flowers in

general as regards to pollen production. Instead of all of the anthers bursting when the bloom opens, the anthers of the outer cycles alone dehisce first, followed gradually by the other cycles as they come to maturity. Flowers of this sort are not completely damaged by one rain-storm, because only the loose pollen is washed away, and when the weather clears up the anthers of the inner cycles mature and are ready to supply all the pollen needed by its own flower and the flowers that might be in the vicinity.

TABLE No. 8

BLOOMING PERIODS OF DEWBERRIES AND BLACKBERRIES.

DEWBERRIES.

Variety	1910 First Bloom	1911 First Bloom	1915 First Bloom	1915 Last Bloom
Austin.....	Apr. 5	Apr. 17	Apr. 20	May 14
Chestnut.....	Apr. 4	Apr. 20	Apr. 19	May 24
Cox.....	Apr. 5	Apr. 20	Apr. 20	May 14
Ruth.....	Apr. 5	Apr. 21	Apr. 24	May 21
Grandee.....	Mar. 31	Apr. 20	Apr. 19	May 14
Limekiln.....	Mar. 31	Apr. 20	Apr. 20	May 20
Lucretia.....	Apr. 5	Apr. 21	Apr. 24	May 22
Haupt.....		Apr. 28	Apr. 20	May 19
Manatee.....	Apr. 4	Apr. 14	Apr. 19	May 19
Munroe.....	Apr. 4	Apr. 17	Apr. 19	May 20
Prem.o.....	Apr. 5	Apr. 17	Apr. 24	May 16
Elijah, No. 2.....	Apr. —	Apr. 17	Apr. 15	May 19
Rogers.....	Apr. 4	Apr. 14	Apr. 12	May 14
San Jacinto.....	Apr. 4	Apr. 17	Apr. 15	May 14
White.....	Mar. 31	Apr. 17	Apr. 14	May 15

BLACKBERRIES.

Blowers.....	May 1	Apr. 24	Apr. 29	May 21
Dallas.....	Apr. 28	Apr. 24	Apr. 25	May 20
E. Cluster.....	Apr. 22	May 1		
E. Harvest.....	May 1	Apr. 24	Apr. 26	May 19
Eldorado.....	May 3		Apr. 30	May 22
Illinois.....	May 1		Apr. 30	May 21
Kenover.....	Apr. 29	Apr. 29	Apr. 26	May 19
King.....	May 3	Apr. 24	Apr. 29	May 22
McDonald.....	Apr. 8	Apr. 17	Apr. 20	May 13
Mersereau.....	Apr. 22	May 3	Apr. 29	May 22
Minnewaski.....	Apr. 22	May 1	Apr. 30	May 22
Rathbun.....		May 1	Apr. 28	May 21
Snyder.....	May 3	Apr. 23	Apr. 29	May 22
Sorsby.....	Apr. 25	Apr. 22	Apr. 24	May 18
Spalding.....	Apr. 27	Apr. 20	Apr. 24	May 18
Wilson.....	Apr. 19	Apr. 23	Apr. 26	May 21

For best results, the blooming periods of the different varieties should be coincident so far as possible. This is especially true when only a very few varieties are under consideration. The earliest and the last blooms require a pollinator equally as potent as do those blooms from which the main crop is expected. In the consideration of several to

many varieties, which are intended to cover the whole fruiting season, it is necessary only to have the blooming period of some varieties overlap at all times, so that at no time in the booming season should we find but one variety in flower.

From the above table we learn that all of the earliest blooming dewberries belong to the species *Rubus trivialis*, which are self-sterile. Consequently, in selecting pollinators we must select such varieties as bloom at the same time, regardless of the fact that they are self-sterile.

The blooming period of dewberries lasts about four weeks. Straggling blooms may be found at all times during the fruiting season, but they may be safely disregarded, for there are not enough of them to warrant the time wasted in the gathering of the resultant fruits.

The blooming period for the blackberries seems to be a little shorter than that for the dewberries. Stragglers are here found mostly among the blackberry-dewberry hybrids, while the true blackberries seem to have a more definite blooming period.

Self-fertile vs. Self-sterile Varieties to be Used as Pollinators for the Berry Plantation.—From evidence disclosed elsewhere in this bulletin, it becomes evident that the requirements of pollinators need not necessarily hinge on the question of self-fertility of varieties, for we found that with one exception a self-sterile variety will readily cross with other self-sterile varieties; but the fact must be kept in mind that self-sterile varieties generally possess in a less degree the qualifications for a good pollinator; that self-fertile varieties will set fruit in bad as well as in good blooming seasons, and that the flowers of self-fertile varieties, whose blooming periods do not overlap, will nevertheless produce an abundance of perfect fruit, while those of the self-sterile varieties may not. For these reasons the self-fertile varieties of dewberries and hybrids that are grown either as dewberries or as blackberries ought to be given preference whenever possible in the selection of pollinators for the berry plantation.

Comparisons of Fruits from Self-fertilized and Cross-fertilized Flowers.—Leaving out of consideration the question of parthenocarpy, we find that in fruits generally those flowers that are cross-pollinated usually produce larger and better fruits than those that are self-pollinated. Whether this factor is of sufficient importance in the production of dewberries and of blackberries is a question worthy of consideration.

In order to investigate the probable effect of cross-pollination over that of self-pollination with varieties of dewberries and blackberries and their hybrids, two lots of flowers from each of two representative varieties of each type were selected. Lucretia and Austin were chosen to represent the dewberries; Early Harvest and Snyder, the blackberries; and Wilson and Cox, the hybrids. Each lot of the different varieties consisted of large branches with flowers clusters in as nearly the same stage of maturity as it was possible to find. All of these branches were covered alike with cloth bags: the first lot, in order to prevent cross-

pollination; and the second or check lot, in order to offset the effects of the covering in the first lot. The only difference in the resultant fruits must, then, be due to the origin of the pollen.

The flower clusters were covered, when possible, before any of the flower buds had opened, and such as had opened were carefully re-



FIG. 8.—A flower cluster of Munroe (dewberry), showing an abundance of strong, healthy stamens produced by a self-sterile variety of *Rubus trivialis*.

moved, so as to forestall any results due to activities of insects in their daily search for pollen and nectar. The bags covering the clusters of self-pollinated flowers were never lifted until comparisons of the inclosed fruits were made, while those bags which covered the cross-pollinated

flowers were lifted every day during the blooming season and the inclosed flowers crossed with pollen from other varieties until the last bloom was past the stage of receptivity. After this, these bags were also allowed to remain untouched until the inclosed fruits were ready for comparison.

Results and Discussion.—Of the dewberries, all of the bags were recovered. Both branches of each variety that was self-pollinated differed in no respect from similar branches that had been carefully crossed; nor did they differ from normal branches of fruit that were found in the open and had been left to insect pollination. The individual fruits were much alike in size, shape, color, and general condition.

With the hybrid vines, Wilson and Cox, similar results were obtained.



FIG. 9.—Lucretia dewberry (*Rubus villosus*). A good crop of dewberries produced by a self-fertile vine.

No deleterious effect of selfing was noticed. In the case of the blackberries, Snyder behaved in similar manner. Early Harvest produced two branches of good fruits and two branches of poor fruits; but it so happened that the "selfed" lot, like the "crossed" lot, produced one good branch and also one poor one. In this instance the poor development of fruit cannot be attributed to self-fertilization, but must be ascribed to some other unknown agent that attacked the branches of both plants alike.

It must be remembered, however, that in this experiment only known self-fertile varieties from each type were selected. Had we included partially self-sterile varieties or wholly self-sterile varieties, the results would have been most striking and to the contrary.

From these results we learn that by judicious and careful selection of varieties we may choose one or we may choose more than one variety for our fruit plantation and be reasonably certain of a good setting of fruit. However, under ordinary conditions, several varieties ought to be selected and mixed planting resorted to so as to secure the best possible results from cross-pollination. Cross-pollination causes no deleterious effects on the fruits, and usually is more beneficial in that a better crop may be produced.

In the case of the partially self-fertile varieties, such as Rathbun and of all the recognized self-sterile varieties of dewberries and blackberries a good pollinator is an absolute necessity.

SUMMARY

The results of the investigation as to the self-sterility of varieties of dewberries and of blackberries may be summarized as follows:

1. Among the fifteen varieties of dewberries that were tested for self-fertility, eleven were found to be self-sterile. These eleven varieties are as follows:

Chestnut	Haupt	Rogers	San Jacinto
Grandee	Manatee	Elijah, No. 2	White
Limekiln	Munroe	Premo	

The varieties that are found to be self-fertile are:

Austin	Cox
Ruth	Lucretia

2. Among the sixteen varieties of blackberries that were tested for self-fertility, three were found to be self-sterile, one partially self-sterile, and twelve self-fertile.

The self-fertile varieties are:

Blowers	Early Harvest	Kenoyer	Minnewaski
Dallas	Eldorado	King	Snyder
Early Cluster	Illinois	Mersereau	Wilson

The partially self-sterile variety is the hybrid Rathbun.

The self-sterile varieties are the hybrids:

McDonald
Sorsby
Spalding

3. That some flowers from varieties of dewberries which are here listed as being self-sterile, when self-pollinated, oftentimes produce a very few seeds; and that these seeds apparently are the direct result of self fertilization.

4. That the species *Rubus villosus* generally is self-fertile, but that self-sterile plants or varieties such as Premo, may not be uncommon.

5. That the species *Rubus trivialis*, judging from the results obtained from nine commercial varieties, is self-sterile; and that this self-sterility frequently is transmitted to its hybrid progeny.

6. That the self-sterility among dewberries and hybrid varieties that are grown either as dewberries or as blackberries can be attributed either to a nonattraction or to a repulsion of the sexual elements from the same plant or from the same variety.

7. That self-sterility of dewberry plants and of blackberry plants cannot be attributed to a want of viable pollen.

8. That pollen from most of the self-sterile varieties will successfully fertilize flowers on other self-sterile, or self-fertile varieties.

9. That fully self-fertile dewberry plants and blackberry plants, when self-pollinated, produce apparently as good fruits as when cross-pollinated.

